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by A. J. Miller, H. M. Woolf, and F. G. Finger

ESSA, Weather Bureau, National Meteorological Center
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SUMMARY

Results of comparisons of wind and temperature data obtained by closely spaced launchings of Japanese MT-135 and American ARCAS meteorological rocket systems are presented. In general, smoothed temperature profiles show a certain disagreement that is unexplained at this time. Perturbation profiles of wind and temperature, on the other hand, indicate a high degree of correlation that tends to substantiate the existence of small-scale features.

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INTRODUCTION

While the meteorological rocket data obtained to date have significantly increased our knowledge of the upper atmosphere, a still greater frequency and spatial density of observations are required to fill scientific needs. Accordingly, more and more nations are participating in the current meteorological rocket sounding programs. As in the case of the present radiosonde network, however, the employment of different instruments by the various nations forces the users of the data to consider their compatibility (Teweles and Finger, ref. 12).

A memorandum of understanding was recently signed between Japan and the United States by which Japan sent to the National Aeronautics and Space Administration's station at Wallops Island, Virginia, a contingent of scientists and specialists with ten rockets and instruments of Japanese manufacture. The objective was to compare and cross-calibrate Japan's MT-135 meteorological rocket system with the United States' ARCAS rocket system through nearly simultaneous launchings. A secondary goal was to obtain scientific data in the 20-60-km altitude region on the diurnal cycles of wind and temperature.

Since the individual instruments are described by Spurling and Arizumi (ref. 11), we present below only a brief description of the systems employed. The MT-135 Echo-Sonde (ES-64B) descends from apogee by parachute and contains a transponder, which upon interrogation by a 1673 MHz signal transmitted from the Japanese radar (RD-66), responds with two pulses on a frequency of 1687 MHz. The first return pulse is the range pulse and the second pulse transmits temperature information by its position in time relative to the range pulse. The actual temperature sensor consists of 17 cm of 20 micron ($\approx$ 0.8 mil) iron-nickel resistance wire strung on a rectangular frame, approximately 43 mm by 10 mm, attached to the side and extending outward from the descending instrument package. The deceleration device employed is a 4-meter diameter silk parachute. Radar range and angular position data are used to calculate the position of the descending sonde, from which the speed and direction of the wind are determined.

The Arcasonde 1A also descends by parachute, but in contrast to the Japanese procedure the wind and temperature information are determined by

TABLE 1. Typical Data Format Employed by Japan

1628 GMT 4 APR. 1967 Wallops Station

Time Difference (sec)	Ht. 10M	West Wind M/S	South Wind M/S	Direct. DEG.	Speed M/S	Ht. 10M	Temp. 0.1C
10	5249	26	- 7	285	27	5488	103
10	5162	25	- 5	281	25	5425	26
10	5081	28	- 1	273	28	5407	13
15	5000	33	- 4	276	33	5360	39
20	4899	46	- 6	278	46	5307	- 10
25	4773	42	5	263	42	5179	14
30	4627	42	14	252	44	5016	25
30	4467	42	17	248	46	4918	17
30	4333	34	14	248	37	4547	- 55
30	4196	34	17	243	38	4333	-136
30	4081	32	19	239	38	4150	-166
30	3971	28	7	256	29	3971	-156
30	3862	34	- 5	279	35	3812	-232
30	3763	46	- 3	274	46	3648	-265
30	3676	52	5	265	52	3614	-264
30	3591	47	6	263	47	3498	-323
30	3510	40	3	266	40	3437	-304
30	3437	38	3	265	39	3315	-357
45	3336	36	8	257	37	3191	-423
45	3240	31	10	253	33	3132	-418
60	3122	23	10	247	25	2914	-460
60	3017	17	10	238	20	2726	-474
60	2922	14	10	234	17	2639	-494
60	2824	10	7	234	12	2566	-502
60	2732	8	5	238	10	2474	-529
60	2664	10	4	249	11	2381	-527
60	2576	9	4	248	10	2345	-541
60	2500	7	3	245	8	2235	-569
60	2430	5	2	250	5	2157	-548
60	2362	5	0	274	5	2054	-556
90	2275	7	- 1	276	7	2000	-593
90	2188	7	0	274	7	1966	-585
120	2081	10	- 1	274	10	1944	-605
120	1974	11	- 2	280	11	1916	-600
120	1884	12	- 5	292	13	1888	-613
120	1796	15	- 4	286	15	1842	-584
120	1711	17	- 1	274	17	1804	-589
	1639	17	0	270	17	1782	-631

means of two separate ground-based systems. Temperatures are measured by a nominally 10-mil aluminized bead thermistor mounted so as to face downward as it descends through the atmosphere. The information is telemetered to the ground on a carrier frequency of 1680 MHz and is received by rawin set (AN/GMD-1B with a parametric amplifier). Positions of the metalized parachute, from which wind direction and speed are determined are computed from the range and angular position data obtained by a high-resolution radar system. For this series of soundings, 16-foot diameter disc-gap-band parachutes were employed with the Arcasonde 1A (Eckstrom, ref. 5).

The purpose of this report is to present the results of the comparison tests held on 4-5 April 1967 and to illustrate the feasibility of employing the above instruments to measure the small-scale wind and temperature structure. Previous studies concerned with the detailed structure of the middle atmosphere have been limited mainly to wind information obtained by radar tracking of rising balloons and falling spheres (e.g. Newell et al., ref. 10; Lettau, ref. 6; Weinstein et al., ref. 15). The present study gives the first indication of such structure as measured by fine-resolution observations of parachute wind sensors and of the accompanying temperature structure.

Information concerning the diurnal cycles of wind and temperature is not presented here, per se, as it is felt that further inquiry into this vital subject is needed.

DATA

As stated above, wind speed and direction were determined in both systems from the range and angular position of the descending sonde. The Japanese used a time-based technique and calculated the differences in position of the sonde at time intervals that increased with time, so that the altitude interval between points was relatively constant. (Table 1 presents a sample output page of the Japanese reduction.) The computed wind value was assigned to the height that was determined at the mid-point of the time interval by a first-order Taylor series. Temperatures were determined from the temperature-versus-time recorder trace, with 1° departure from linearity employed as the criterion for a significant level (2° departure from linearity is the commonly employed criterion). Temperature-heights were interpolated, in the same manner as above, between the levels used as input in the wind calculations.

The wind determination scheme employed by Wallops Island personnel for the ARCAS data (Table 2 presents a sample wind tabulation form) which is also that employed by the current Experimental Inter-American Meteorological Rocket Network (EXAMETNET) participating stations, is based on a constant altitude difference between measured points. In this method, the time of the sonde's position at 1 km above and 1 km below every whole kilometer level was subjectively interpolated from the radar (AN/FPS-16) plot board (one point every 10 seconds). Temperatures were determined from the temperature-versus-time recorder trace with 1° departure from linearity employed as the criterion for a significant level. The heights associated with the temperature values were obtained from a computer output (described below) with height determined at one-second intervals.

TABLE 2. Met Rocket Winds Tabulation Form Employed at Wallops Island, Va.

1643 GMT 4 APR. 1967 Wallops Station

Altitude Km	Time at Level min-secs	Time Upper Level min-secs	Time Lower Level min-secs	Δ T secs	Displacement Ft.	Wind Dir. deg.	Wind Spd Kts	Components mps N-S	Components mps E-W
50	3:17	3:05	3:27	22	2100	273	57	-2	29
49	3:27	3:17	3:41	24	2600	275	64	-3	33
48	3:41	3:27	3:56	29	3900	274	80	-3	41
47	3:56	3:41	4:11	30	4400	268	87	2	44
46	4:11	3:56	4:28	32	4900	266	91	4	46
45	4:28	4:11	4:45	34	5350	261	93	7	47
44	4:45	4:28	5:04	36	5450	250	90	16	43
43	5:04	4:45	5:25	40	5850	248	87	17	42
42	5:25	5:04	5:50	46	6900	255	89	12	45
41	5:50	5:25	6:10	45	5900	251	78	13	38
40	6:10	5:50	6:39	49	4750	241	57	14	26
39	6:39	6:10	7:03	53	4650	252	52	8	25
38	7:03	6:39	7:34	55	5900	269	63	1	32
37	7:34	7:03	8:10	67	9550	271	84	- 1	43
36	8:10	7:34	8:44	70	10500	266	89	4	45
35	8:44	8:10	9:20	70	9500	265	80	3	41
34	9:20	8:44	9:56	72	8900	262	73	5	37
33	9:56	9:20	10:40	80	9700	257	72	9	36
32	10:40	9:56	11:23	87	9400	254	64	9	31
31	11:23	10:40	12:20	100	9200	248	54	10	26
30	12:20	11:23	13:14	111	8150	242	43	10	19
29	13:14	12:20	14:18	118	6400	234	32	10	13
28	14:18	13:14	15:28	134	5800	235	26	8	11
27	15:28	14:18	16:40	142	5100	236	21	6	9
26	16:40	15:28	18:04	156	4700	243	18	4	8
25	18:04	16:40	19:25	165	3850	249	14	3	7
24	19:25	18:04	20:55	171	2900	254	10	1	5
23	20:55	19:25	22:25	180	3100	267	10	0	5
22	22:25	20:55	24:15	200	5000	271	15	0	8
21	24:15	22:25	26:15	230	6300	273	16	0	8
20	26:15	24:15	28:30	255	7700	274	18	- 1	9
19	28:30	26:15	30:00	225	9100	286	24	- 3	12

Both methods of wind determination filter variations of smaller vertical dimension than the height interval of the calculations. Therefore, in order to assess the possible existence of small-scale motions, fine resolution radar data were obtained in addition to that described above. An AN/FPQ-6 radar (range precision $\approx$ 5 m; angular precision $\approx$ 0.05 mil (1 mil = 0.05626°)) tracked the Japanese instrument in addition to the RD-66 radar (range precision $\approx$ 30 m; angular precision $\approx$ 1 mil) and recorded, on magnetic tape, data points at every tenth of a second. The AN/FPS-16 radar (range precision $\approx$ 5 m; angular precision $\approx$ 0.1 mil) was the primary radar employed in tracking the ARCAS payload, and hence data were obtained both on the plotting board at 10 second intervals and on magnetic tape at 0.1 second intervals. Smoothed position information was obtained from the two sets of fine resolution data by employing a 9-point running mean on the 0.1 second data. Winds were then calculated by finite differences (rounded to whole meter per second) at 1-second intervals from the smoothed data, and positioned at the time mid-point.

Figures 1 and 2 present typical wind profiles obtained from the fine resolution computer-processed position data. Also plotted are the wind profiles determined by the Japanese and Wallops Island techniques. As mentioned above, the fine vertical structure indicated by the computer data is almost completely suppressed by the other methods. In addition, it is apparent that the discrete sampling of the detailed structure and the method of interpolation occasionally cause aliasing (Blackman and Tukey, ref. 3) in the smoothed data. While it is not obvious from the scale of Figures 1 and 2, each perturbation of the computer results is based on about 20-30 data points and is, therefore, not simply "noise" in the receiving equipment.

Table 3 gives the launch schedule and the general performance characteristics of each sonde. As mentioned above, 10 MT-135 rockets were available for the entire series. Since the 0910Z and 1107Z soundings did not achieve temperature records, it was necessary to modify the original schedule in consideration of the diurnal variation experiment, and the schedule shown here was established. The non-uniform time differences between soundings were due to operational limitations at the time of launch. The soundings on March 31 were made as a systems test.

While the main factor in determining the success-versus-failure rating of each sounding was the availability of temperatures, it should be noted from Table 3 that in several instances, the radar data at 0.1 second intervals were not available for certain periods covering portions of or even entire soundings. For these periods radar plotting board information at 10 second intervals was utilized.

Figure 3 shows the position of each sonde relative to Wallops Island at the highest level of winds determined from the fine resolution data (Table 3). This level was chosen for presentation despite the fact that it is not the same for all sondes because coincident comparisons could not be made at any fixed level. The horizontal dispersion indicated, although not beneficial to this particular experiment, was unavoidable as the launch angles of the rockets were determined by range safety considerations of sea traffic and the response of the rockets to low level winds.

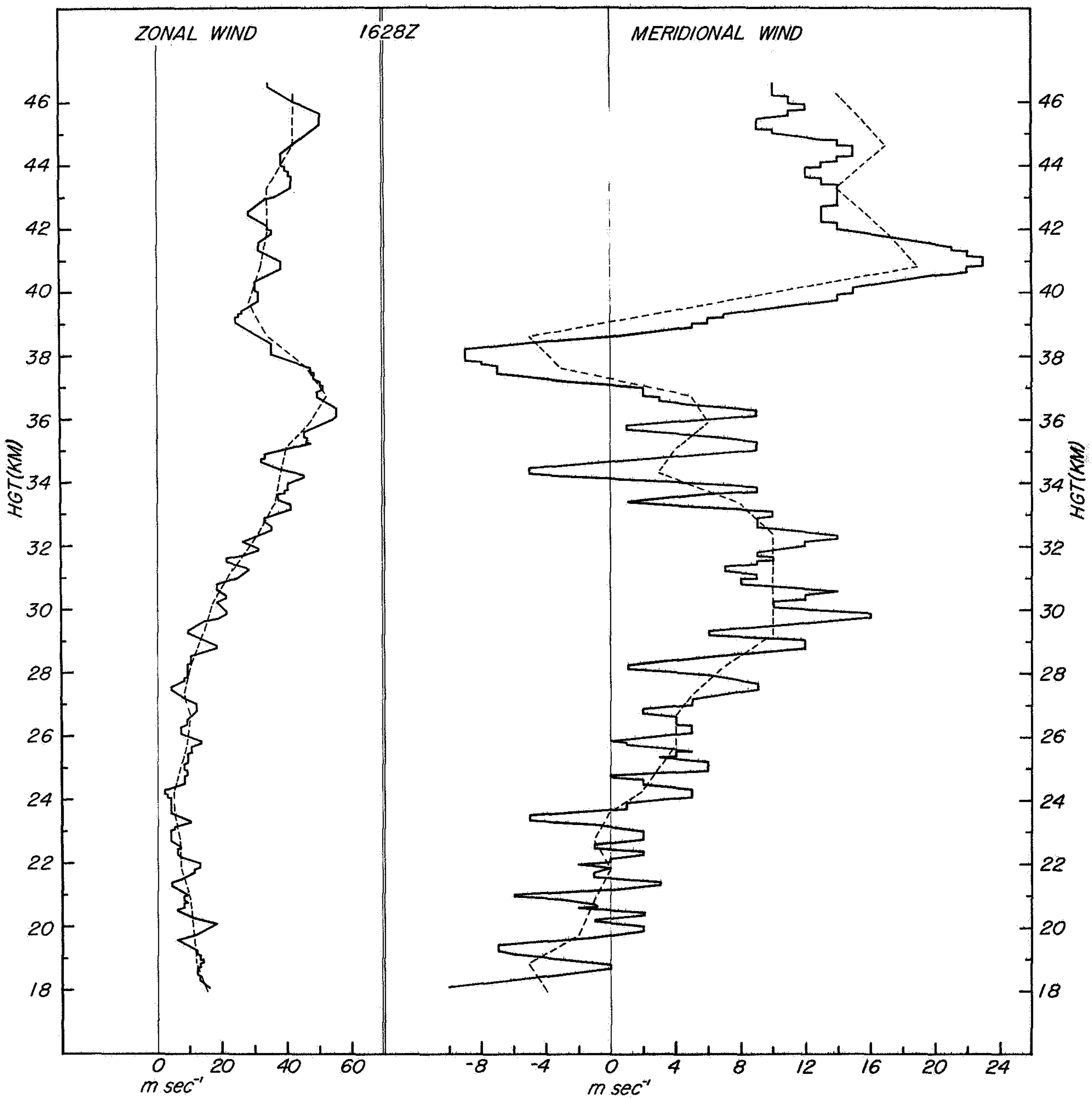

Figure 1. Zonal and meridional wind components from the 1628 GMT MT-135 observation. Solid line: fine-resolution radar winds plotted at 1-sec intervals. Dashed line: winds determined by Japanese technique.

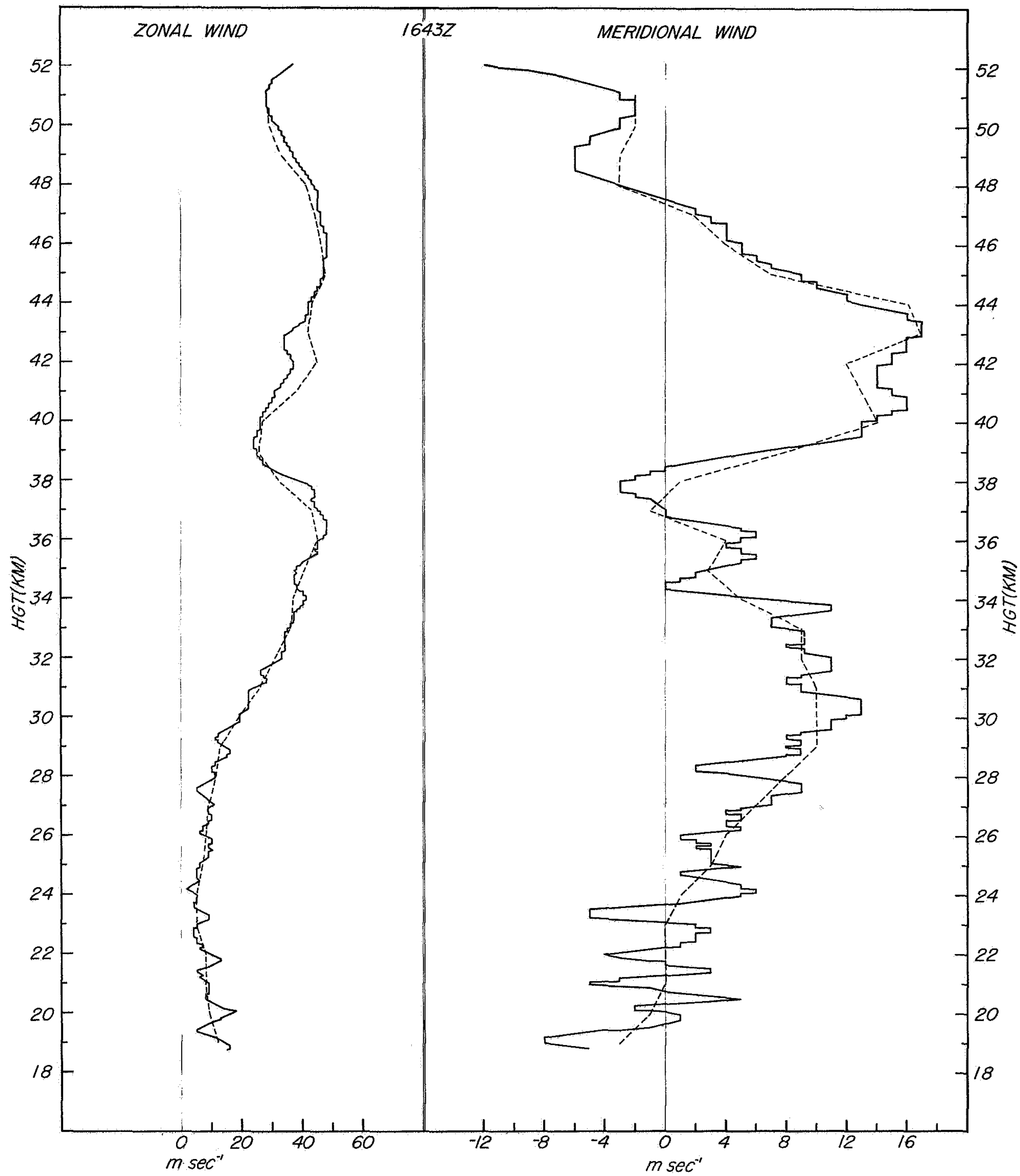

Figure 2. Zonal and meridional wind components from the 1643 GMT ARCAS observation. Solid line: fine-resolution radar winds plotted at 1-sec intervals. Dashed line: winds determined by Wallops technique.

TABLE 3. JAPAN - UNITED STATES METEOROLOGICAL ROCKET PROJECT

PERFORMANCE CHARACTERISTICS

LAUNCH TIME GMT	APOGEE (KM)	MAXIMUM ALTITUDE OF FINE RESOLUTION WIND DATA (KM)	TEMPERATURE MEASURING PERFORMANCE
		MT-135	LAUNCHINGS
Mar. 31, 1967 - 1828	53.6		Good
Apr. 4, 1967 - 0910	53.8	38.0	N/A*
Apr. 4, 1967 - 0955	57.2	38.9	Good
Apr. 4, 1967 - 1107	54.3	39.6	N/A
Apr. 4, 1967 - 1156	57.1	45.9	Good
Apr. 4, 1967 - 1528	55.2	46.6	Good
Apr. 4, 1967 - 2244	56.0	45.6	Good
Apr. 5, 1967 - 0017	55.8	48.2	N/A
Apr. 5, 1967 - 0101	53.6	47.4	Good
Apr. 5, 1967 - 0333	56.5	49.6	N/A
		ARCAS	LAUNCHINGS
Mar. 31, 1967 - 1844	58.2		Good
Apr. 4, 1967 - 0927	62.5	50.2	N/A
Apr. 4, 1967 - 1002	58.8	52.3	Good
Apr. 4, 1967 - 1119	52.3	47.2	Good
Apr. 4, 1967 - 1643	58.3	52.0	Good
Apr. 4, 1967 - 1902	60.2	56.0	Good
Apr. 4, 1967 - 2259	59.1	56.7	Good
Apr. 5, 1967 - 0032	52.6	49.8	Good
Apr. 5, 1967 - 0129	61.0	58.3	Good
Apr. 5, 1967 - 0358	60.5	55.0	Good

* N/A - Not Available

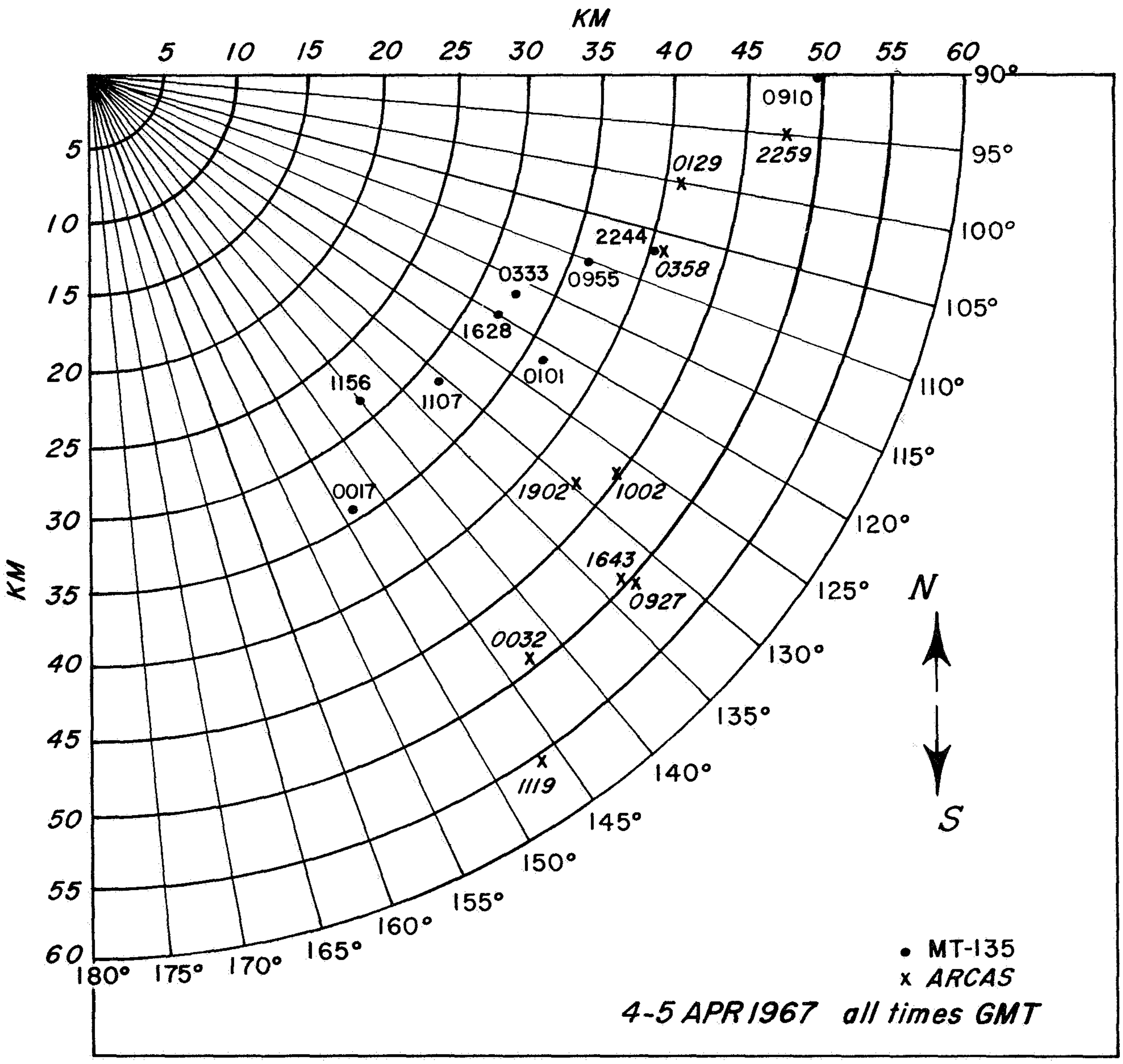

Figure 3. Sonde positions relative to Wallops Island at highest level of winds determined from computer processed radar data.

Inspection of all wind profiles indicated that if we were to evaluate the small-scale features properly, the overall trend in each curve would have to be removed. Accordingly, the winds were smoothed by a 1-2-1 weighted average smoothing at 500 meter intervals ($\bar{U}_z = 0.25\,U_{z-500} + 0.50\,U_z + 0.25\,U_{z+500}$ where U represents either the zonal or meridional wind speed) and values linearly interpolated between the smoothed data points. Deviations from the smoothed profile ($U'_z = U_z - \bar{U}_z$) were then determined at 250-meter intervals. This value of the data interval was chosen only after careful consideration of all the data in diagrams similar to Figures 1 and 2, and represents the smallest interval of apparent wind structure.

The temperature profiles did not indicate as small a vertical scale as the wind, and therefore were smoothed by a 1-2-1 weighted running mean at 1 km intervals. Temperatures (T) were linearly interpolated between the smoothed data points and deviations ($T'_z = T_z - \bar{T}_z$) determined at 500-meter intervals.

The criteria for accepting the above smoothing procedure were as follows:

a) the overall mean of the deviations for each sounding was approximately zero;

b) the magnitude and phase of the perturbations were such that over the full extent of the soundings there were about as many deviations that made the profiles of the time-paired observations of Table 3 more coincident as there were that made them less so.

It should be emphasized at this time that the temperature fluctuations discussed in this paper are not the fluctuations referred to by Ballard (ref. 11), Lindzen (ref. 7) and Beyers and Miers (ref. 2). The oscillations referred to by those authors represent still smaller scales than indicated here and are usually attributed to the oscillatory motion of the instrument as it descends.

DISCUSSION

Comparison of Temperature-Heights Obtained from the RD-66 and AN/FPQ-6 Radars

As described above, the technique presently employed by the Japanese is a linear interpolation of temperature heights from the altitudes used in the wind calculations. However, it has been shown (Miller and Woolf, ref. 9; Spurling and Arizumi, ref. 11) that the height-versus-time relationship is more nearly exponential. Consequently, we should expect that in addition to a possible random inaccuracy imposed by the resolution of the radar the interpolated values will be in error, the magnitude increasing with height. As a test of this hypothesis, the Japanese height determinations were compared with the computer-processed AN/FPQ-6 radar heights. A typical comparison is presented in Table 4.

In general, the interpolated values are higher than the AN/FPQ-6 determined heights, with the differences tending to increase with altitude. These results indicate that the temperatures would be more precisely located if

TABLE 4. Differences between altitudes assigned to temperature measurements as determined by FPQ-6 computer processed radar data and Japanese interpolation program.

1628 GMT 4 APR. 1967 Wallops Station

JAPAN HT(m)	TEMP. 0.1°C	FPQ-6 HT(m)	HT DIFF. J-FPQ-6(m)
46970	- 23	46500	470
46160	- 29	45722	438
43770	-117	43284	486
41770	-176	41348	422
41000	-157	40587	413
39710	-157	39325	385
39270	-191	38904	366
38940	-186	38592	348
38290	-239	37972	318
37630	-232	37335	295
36110	-265	35788	322
34980	-323	34716	264
34350	-303	34102	248
33080	-344	32835	245
31810	-423	31611	199
31320	-417	31149	171
29190	-459	29046	144
27300	-473	27218	082
26930	-492	26754	176
25730	-494	25651	79
24740	-531	24674	66
23830	-529	23755	75
23410	-544	23331	79
22590	-536	22494	96
22350	-569	22246	104
21710	-544	21600	60
20540	-557	20480	60
20370	-563	20311	59
20120	-594	20087	33
19660	-584	19651	9
19460	-598	19445	15
19270	-590	19254	16
18820	-610	18809	11
18420	-583	18406	14

matched in time with measured heights. Because of this discrepancy, all other comparison tests used temperature-heights obtained from the computer-processed AN/FPQ-6 data.

Comparison of Temperatures Obtained by ES-64B and Arcasonde 1A Systems

Figure 4 presents the smoothed and perturbation temperature profiles for the 8 soundings (4 MT-135, 4 ARCAS) for which the comparisons could be made using computer processed radar data. The altitudes of the 0129 GMT sounding had to be interpolated from the radar plotting board (positions marked every 10 seconds) because a ground equipment recording malfunction reduced the length of the computer record. The general level of accuracy of the 0129 GMT height values is about ± 200 meters. Therefore the 0129 GMT and 0101 GMT soundings were not compared in the manner described here.

Examining the smoothed temperature profiles, we detect a certain disagreement between two of the observation-pairs: 0955-1002 GMT and 1119-1156 GMT. While the 0955 GMT sounding was warmer than that at 1002 GMT, the 1156 GMT observation was colder than that at 1119 GMT. Figure 3, however, indicates that the relative physical locations of the sondes did not change in such a manner that we would have expected this reversal. The 1628-1643 GMT and 2244-2259 GMT comparisons, on the other hand, show considerably better overall agreement.

The cause of these disparities is not known, but it should be remembered that our analysis scheme is based on the stipulation that there are about as many perturbations that increase the differences between the actual values as decrease them. In this regard, it is interesting to note that 0955 and 1002 GMT soundings show remarkable similarity in their overall shape, suggesting the possibility of a calibration error in either or both instruments. Contradicting this hypothesis is the fact that the other observations do not exhibit similar systematic differences. Clearly, though, every effort should be made to clarify this situation and to erase all ambiguity concerning such temperature measurements.

The temperature perturbations of these time-paired observations (Fig. 4), in contrast to the above, show very good agreement with each other with a vertical scale of about 1.5-2 km and magnitudes of about ± 2°C. As a measure of this compatibility, correlation coefficients were computed (Table 5). In each instance, the correlation coefficient of these paired observations exceeds the random chance value at the 0.001 level (Brooks and Carruthers ref. 4), as does the 0101-0129 GMT correlation. As the spatial separation of the 1643 and 1902 GMT observations was only about 7 km, their correlation coefficient was computed as a possible indication of the time variance of these perturbations. As indicated in Table 5, the correlation is not significant even at the 0.1 level.

The vertical structure of these perturbations is also of interest as there does not seem to be any marked change of vertical wavelength with height. It must be noted, though, that our analysis is limited by the resolution of the data and our results do not preclude the existence of smaller-scale deviations.

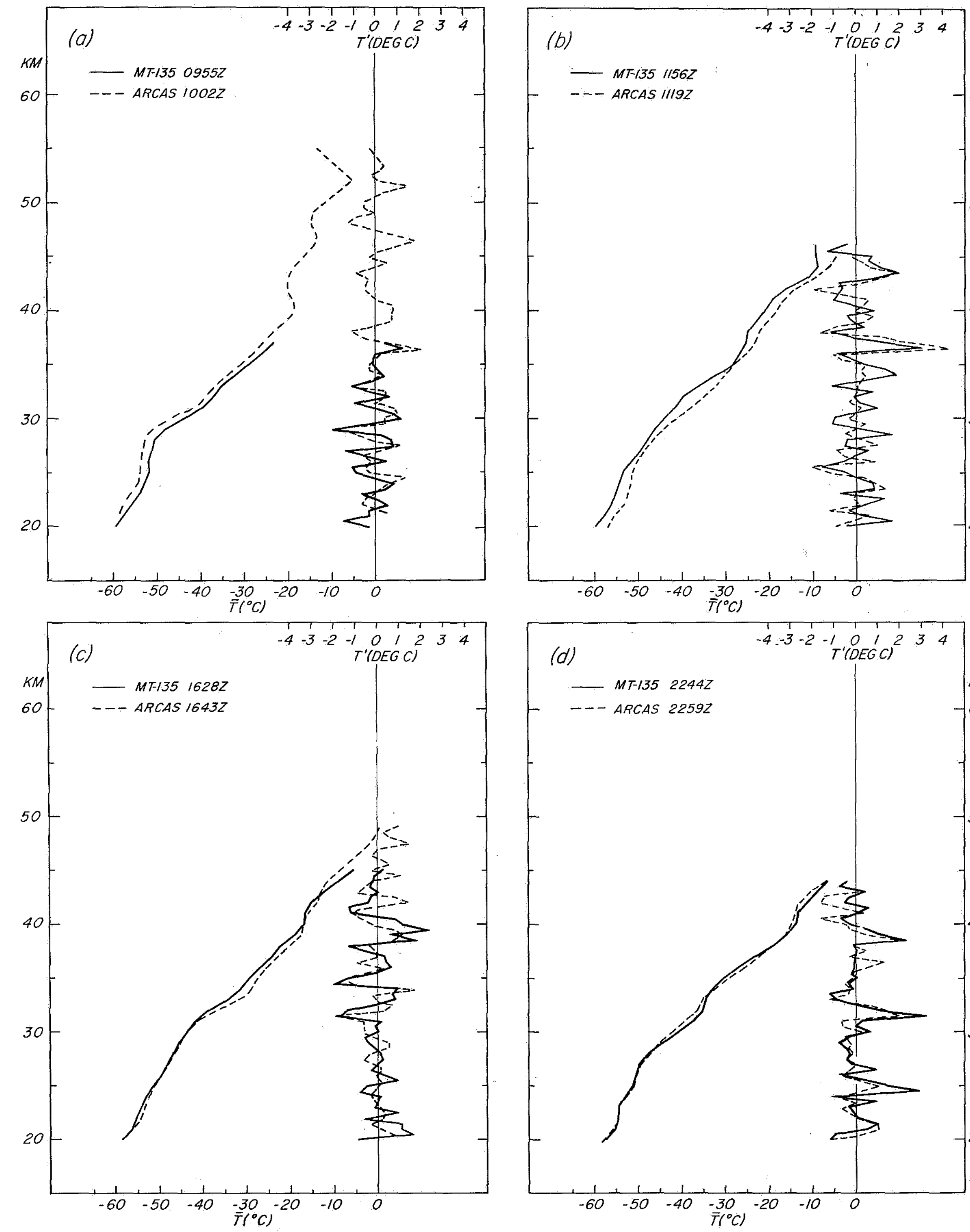

Figure 4. Smoothed (T) and perturbation (T') temperature profiles (all times GMT): (a) 0955 MT-135 - 1002 ARCAS; (b) 1119 ARCAS - 1156 MT-135; (c) 1628 MT-135 - 1643 ARCAS; (d) 2244 MT-135 - 2259 ARCAS.

Comparison of Winds Obtained by ES-64B and Arcasonde 1A Systems

Figures 5 and 6 present the smoothed and perturbation profiles of the zonal and meridional wind components from the 8 soundings for which both temperature and wind comparisons could be made.

Noting first the smoothed wind profiles, we see that there is, in general, relatively more agreement between the two wind determinations than between the temperature measurements (Fig. 4). Especially lacking is the overall bias that appeared in several of the temperature comparisons. Once again, this suggests calibration problems as a possible source of the smoothed-temperature differences.

With respect to the wind perturbations, we see that as in the case of the temperature structure, the profiles are very similar. We note, however, the tendency for the MT-135 perturbation amplitudes to be somewhat greater than those measured by the ARCAS system, especially at the higher altitudes. Assessment of this feature should be tempered by consideration of the two parachute designs (Spurling and Arizumi, ref. 11) and the wind-sensitivity characteristics of the instruments as a function of descent rate (Malet, ref. 8). As Spurling and Arizumi show, the Arcasonde 1A tended to fall at a somewhat faster rate ($\Delta W \approx 2$ to $5\ m\ sec^{-1}$) than the ES-64B during the 1628-1643 GMT and 2244-2259 GMT comparisons. During the 0955-1002 GMT and 1119-1156 GMT comparisons, this difference in fall rate was reduced. The vertical structure of the winds appears to be dominated by a "wavelength" of about 1 km, but as observed by Webb (ref. 14) there is considerable scatter about this value.

In argument against the possibility that the observed wind perturbations are caused by refraction effects on the two radars, it is noted that the AN/FPS-16 and AN/FPQ-6 radars are about one mile apart. Hence, a highly improbable sequence of events would have to occur in order that the index-of-refraction gradients be as similar over the two radar sites as the correlation coefficients indicate. In addition, there is no apparent correlation between the zonal and meridional wind components for each sounding.

As in the analysis of the temperature measurements, correlation coefficients (Table 6) were computed as an indication of the comparability. Since winds were measured even in the event of temperature sensor failure, several other correlations could be computed in addition to those mentioned above. Each sounding was not correlated with all other soundings, since the position information (Fig. 3) suggested that this would only tend to confuse the overall interpretation. Consequently, a correlation coefficient was computed only when two soundings were closely spaced in either time or distance.

In all instances the correlation coefficients were highly significant, exceeding the random chance value at about the 0.001 level. It is unfortunate, however, that the variable horizontal separations of the sondes were not coupled with constant time differences, or vice-versa, so that more meaningful interpretations could be made. The several theories that pertain to the existence of these perturbations (e.g. Weinstein et al., ref. 15; Try, ref. 13; Newell et al., ref. 10) are dependent on the scales of motion involved, and

TABLE 5 Correlation Coefficients of Temperature Perturbations (times in GMT)

Paired Observations	0955 -1002	1119 -1156	1628 -1643	2244 -2259	0101 - 0129
r	0.533	0.545	0.527	0.565	0.464
No. Data Points	33	51	51	49	53

Paired Observations	1643 -1902
r	0.100
No. Data Points	59

TABLE 6. **Correlation Coefficients of Zonal and Meridional Wind Components** (times in GMT)

Paired Observations	0955 -1002	1119 -1156	1628 -1643	2244 -2259	0910 -0955
Zonal Wind	0.407	0.303	0.524	0.498	0.459
Meridional Wind	0.556	0.552	0.649	0.652	0.463
No. Data Points	75	111	107	93	73

Paired Observations	0927 -1002	1107 -1156	1643 -1902	0017 -0032
Zonal Wind	0.443	0.487	0.397	0.471
Meridional Wind	0.786	0.451	0.359	0.531
No. Data Points	65	81	129	89

TABLE 7. **Lag-Correlations of Temperature and Total Velocity Perturbations.**

Lag Positive When Velocity Heights Lower Than Temperature Heights.

1628 GMT

LAG(Meters)	0	250	500	750	1000	1250	1500	1750	2000
r	0.0129	-0.169	-0.07	-0.229	-0.027	-0.058	0.002	-0.048	-0.006
No. Data Points	51	51	51	51	51	50	50	49	49

1643 GMT

LAG(Meters)	0	250	500	750	1000	1250	1500	1750	2000
r	0.0876	-0.1007	0.033	0.031	-0.0415	-0.0715	0.004	0.022	0.188
No. Data Points	59	59	59	58	58	57	57	56	56

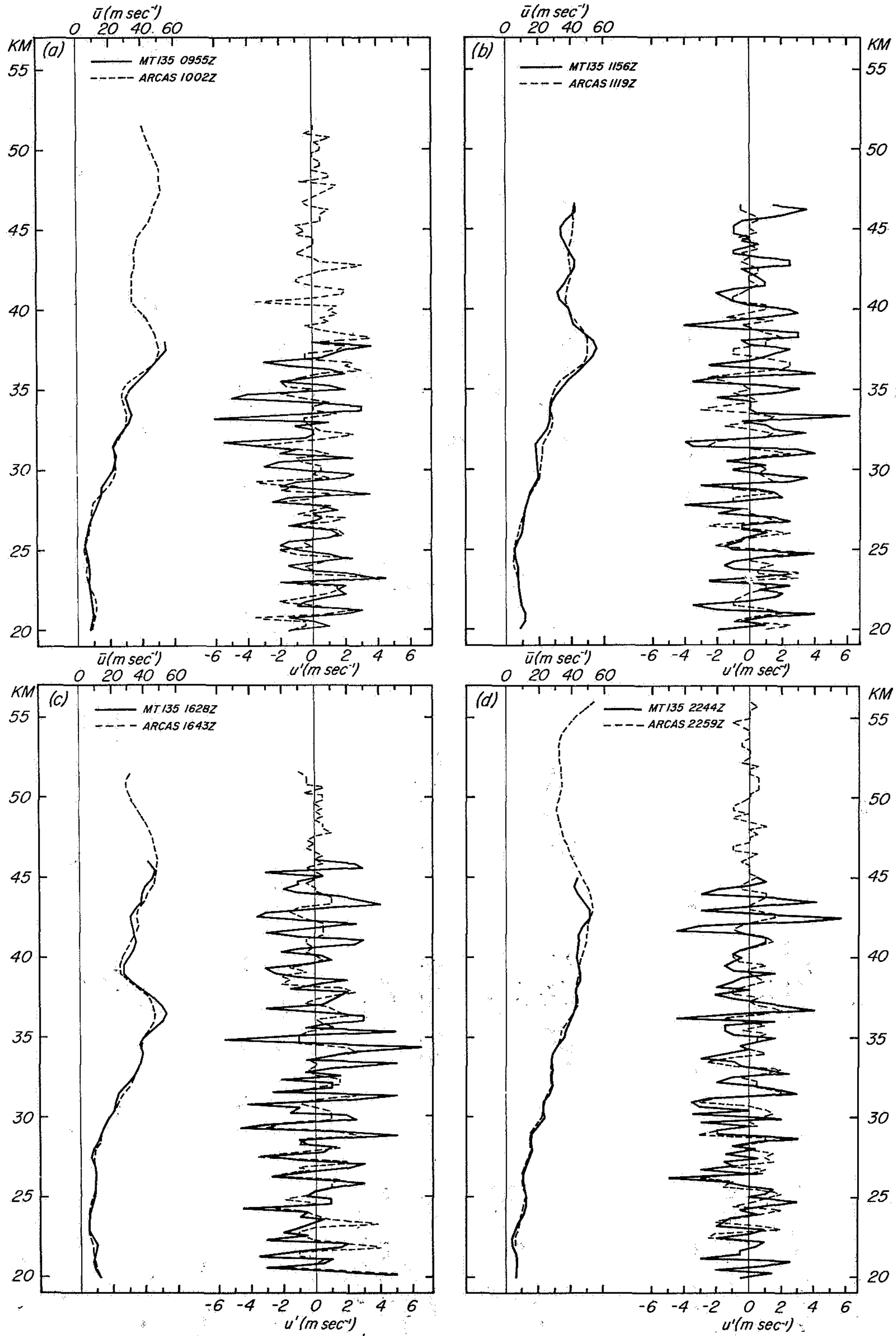

Figure 5. Smoothed (U) and perturbation (U') zonal wind profiles; observations paired as in Fig. 4.

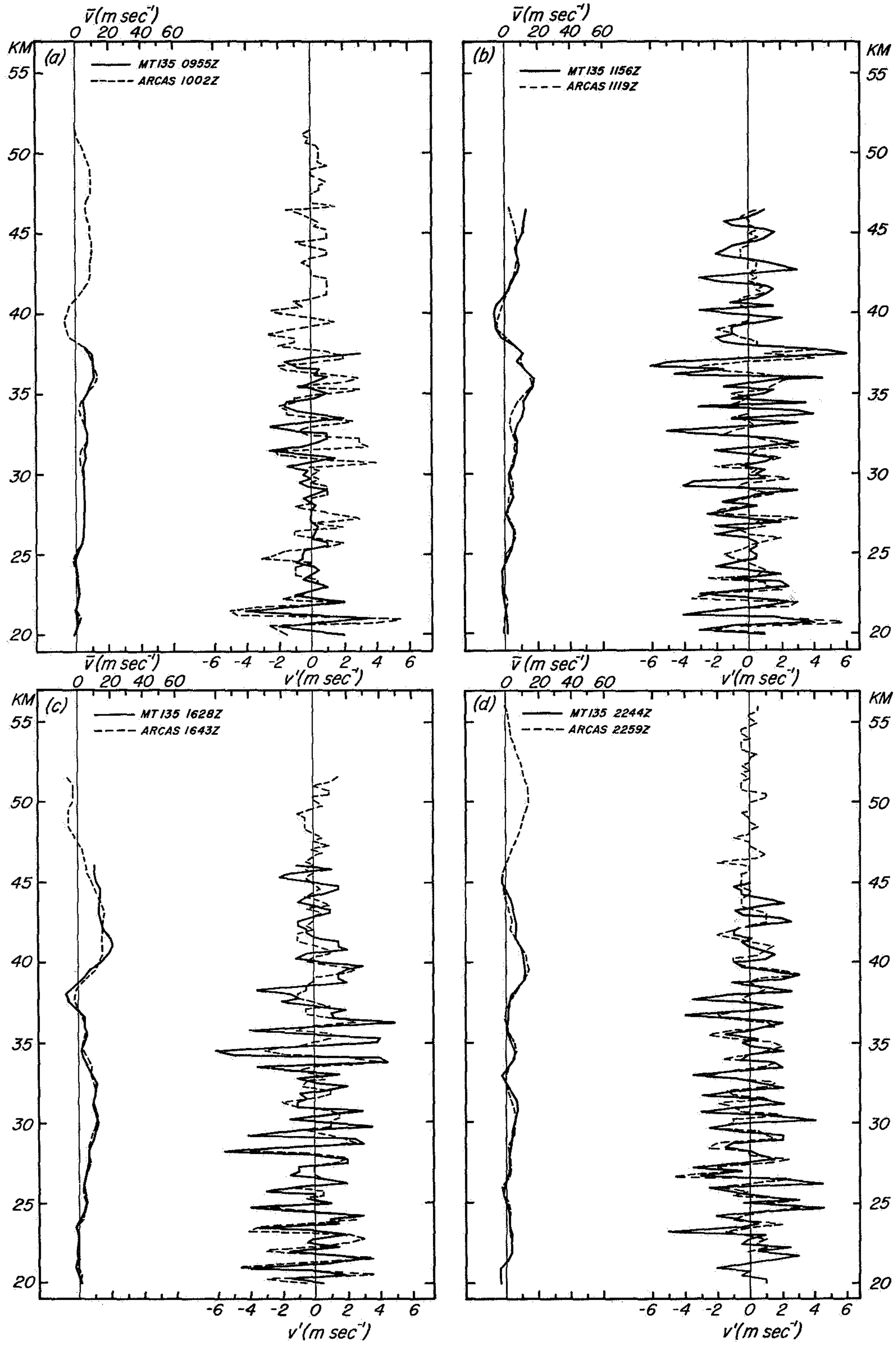

Figure 6. Smoothed (V) and perturbation (V') meridional wind profiles; observations paired as in Fig. 4.

hence information on the four-dimensional structure of the deviations is required.

It is worthy of note, however, that the 1643-1902 GMT comparison displayed a significant correlation of wind, but a non-significant correlation of temperature. The reason for this is not clear at this time, but in view of this result the temperature-wind relationship is discussed below.

Comparison of Temperature Structure with Total Velocity Measurements

As we expect the descending sonde to lag the actual winds in its response to their impulses, lag correlations at 250 meter intervals up to a total separation of 2 km were computed between the temperature deviations and the total velocity deviations for two cases, 1628 and 1643 GMT. Total velocity includes the fall rate of the instrument (i.e. Total Velocity = $(U^2 + V^2 + W^2)^{1/2}$), but the fall rates were found to be so perturbation-free that the final values of deviations from the smoothed values were essentially due to the horizontal winds. The results of the lag-correlation computations are presented in Table 7.

Clearly, there is no indication that the two profiles are correlated at any lag for either instrument type. In fact, none of the correlations is significant even at the 0.1 level. As in the case of the wind comparisons, however, the interpretation of the results of our fairly simple tests should be tempered by the possible non-linear reactions of the descending sonde to the wind fields (e.g. Malet, ref. 8).

FINAL REMARKS

While the overall sample size of the comparisons in this study was limited, we believe that our results have exhibited such consistency that certain general statements can be made:

1) Both the Japanese time-based and Wallops Island height-based methods of computing winds serve effectively to filter out the detailed wind structure as observed by a high-resolution radar. An individual point on either wind profile, however, may be aliased from the perturbation winds and this feature should be borne in mind. Neither method appears to have an advantage over the other so that either technique can be utilized with equal confidence.

2) When the smoothed winds determined from the high-resolution radar data are compared between the two systems, the patterns show considerable agreement. This reflects the similar response characteristics of the two parachutes and increases our level of confidence in this method of wind determination.

3) The temperature heights, as interpolated from the time-sequential heights in the Japanese program, tend to be greater than those measured by the FPQ-6 radar. This is believed to be mainly due to the linear approximation of the instrumental fall rate when, in actuality, it should be more nearly exponential.

4) In two of the four pairs of soundings, systematic temperature differences between the smoothed profiles were noted, which cannot be explained. Further inquiry is needed to determine if they are real atmospheric fluctuations or merely of instrumental origin.

5) When the perturbation values of wind and temperature are compared between systems, a high degree of correlation results that tends to substantiate the existence of these features and raises our level of confidence in the sensitivity of the two instruments. Additional statistical tests indicate that the observed temperature fluctuations are essentially independent of the observed wind oscillations.

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